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SOVIET RESEARCH ON STRESS CORROSION OF METALS

[Comment: This report presents excerpts from the book Issledovaniye Korrozii Metallov Pod Davleniyem (Investigation of the Stress Corrosion of Metals), edited by G. V. Akimov, published in Moscow in 1953 by Mashgiz. The book comprises eight articles giving results of research on the stress corrosion of metals conducted at the Central Scientific Research Institute of Technology and Machine Building.]

EFFECT OF ATMOSPHERIC CORROSION ON FATIGUE STRENGTH OF STRUCTURAL STEEL

A. V. Ryabchenkov, Candidate of Technical Sciences

Ye. L. Kazimirovskaya, Engineer

Introduction

One of the most common types of metal corrosion is atmospheric corrosion.

About 80% of all metal structures are subject to atmospheric corrosion. Millions of tons of metal are annually used to replace corroded structures.

Available experimental data and practical observations indicate that the corrosion of structural and low-alloy steels is considerably increased in industrial and seashore regions. This decrease in corrosion resistance is caused by the salt particles and corrosion-active gases present in the atmosphere.

All data on the atmospheric corrosion of metals in both Soviet and foreign literature are concerned with metal in a static condition. There is no information on the effect of atmospheric corrosion on the fatigue strength of metal.

This article, therefore, attempts to establish a method for testing corrosion fatigue under conditions of atmospheric corrosion and to study the effect of various atmospheric conditions on the fatigue strength of grade 45 structural steel.

Method

Corrosion-fatigue tests were conducted on the YaK-8 machines designed by S. I. Yatskevich. The machines were specially adapted for running fatigue tests under atmospheric corrosion conditions; they were capable of measuring the fatigue strength of specimens subjected to symmetrical flexure at a frequency of 2,800 cycles per minute. [Comment: Article contains line drawing and description of machines.]

The steel tested, grade 45, has the following chemical composition: 0.44% C, 0.28% Si, 0.68% Mn, 0.017% S, and 0.023% P. Before the fabrication of the test specimens, the steel blanks were normalized at 840-860°C. Inasmuch as the rate of corrosion increases as the air humidity and the aggressive gas content of the atmosphere increase, the corrosion-fatigue tests were run in three media: in air, in a humid atmosphere in which the relative humidity was near 100%, and in a humid atmosphere in which the relative humidity was near 100% and which contained sulfur dioxide.

In running the tests in these media, the specimen was hermetically sealed in a special container so that its gauge length was fully exposed to the corrosive medium in the container. To create a humid air medium, 100 cc of distilled water was introduced into the container through an opening near the bottom. The gauge length of the specimen was then situated above the water and was thus subject to the corrosive action of the humid air.

To create the third medium, an 0.02-N concentration of sulfurous acid was poured into the bottom of the container. The medium in the container then contained sufficient quantities of SO_2, H_2O, and air.

Test Results

The test results indicate that humid air decreases fatigue strength 11.5 percent more than air at room humidity, while humid air with an 0.27% SO_2 content decreases fatigue strength by 18.2%.

From these data it may be concluded that the corrosion-fatigue resistance of grade 45 steel is noticeably decreased in an atmosphere of humid air and especially so in the presence of SO_2. [Comment: Article includes sketch of external appearance of specimens subjected to corrosion-fatigue tests in various atmospheric media.] Tests conducted in room air caused practically no visible corrosion. The surface of specimens tested in humid air had a noticeable corrosive coating of a relatively thin and porous film which could be easily removed, thus indicating a weak bonding to the metal, especially in the zone of maximum stress. In specimens subjected to a humid air and SO_2 medium, a comparatively thick layer of corrosive products was formed.

The metallographic examination of specimens subjected to corrosion-fatigue tests in pure humid air and humid air-SO_2 media indicated corrosion-fatigue fractures in the zone of maximum stress.

Conclusions

Atmospheric corrosion in a humid atmosphere or especially in the presence of sulfur dioxide significantly decreases the alternating stress strength of grade 45 structural steel.

Experimental data indicate that reliable fatigue strength index of parts subjected to natural atmospheric conditions cannot be obtained without taking into consideration the effect of the surrounding medium.

These experiments pose for researchers a new task having great practical importance -- the development of means to increase the corrosion-fatigue strength of the grade 45 steel subjected to atmospheric corrosion.

Literature

[Comment: Article lists a 1945, 1949, and 1951 Soviet source and a 1937 German source.]

SURFACE HARDENING AS A MEANS OF INCREASING CORROSION-FATIGUE STRENGTH UNDER ATMOSPHERIC CORROSION CONDITIONS

A. V. Ryabchenkov, Candidate of Technical Sciences
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Introduction

The surfaces of machine parts operating under dynamic stress have a decreased fatigue strength. It follows, therefore, that as a whole the alternating stress strength of the part depends largely on the condition of the surface.

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To increase the strength and service life of machine parts subject to alternating stress, contemporary machine-building practice makes wide use of surface strengthening measures such as cold hardening, induction hardening, and thermochemical treatment.

Such hardening, however, can be consequential only in increasing the strength of smooth steel parts free of any stress raisers.

The authors tested three types of surface hardening: cold shot blast hardening, induction hardening, and nitriding.

Tested Material and Corrosive Media

All corrosion-fatigue tests were conducted on YaK-8 machines designed by S. I. Yatskevich. The machines were capable of measuring the fatigue strength of specimens subjected to symmetrical flexure at a frequency of 2,800 cycles per minute in various atmospheric media. Structural steel, grade 45, was used as the test material; the steel has the following chemical composition: 0.44% C, 0.28% Si, 0.58% Mn, 0.017% S, and 0.023% P. Before the fabrication of the test specimens, the steel blanks were normalized at 840-860°C.

Tests were run in two corrosive media: in air with a relative humidity of 56% and in air with a relative humidity of about 100% containing 0.27% SO_2. [Comment: The method used was the same as used in the experiment described in the first article.]

Test Results on Shot Blast Hardened Specimens

Cold hardening is widely used in the machine-building industry. It has been established that cold hardening increases the strength of metal, particularly fatigue strength. The plasticity of metal is only inconsequentially changed by cold working while stress-raiser induced fractures are considerably decreased. Surface hardening has two effects on the alternating-stress strength of metal: it increases the surface strength of the metal while also creating favorable changes in the surface stress.

Cold working the surface also increases the corrosion-fatigue strength in neutral and weak-acid corrosive media.

Shot blast hardening increased the corrosion resistance of grade 45 steel specimens by 102% in a 3% solution of NaCl, and by 164% in a solution of 0.5 N. NaCl + 0.01 N·HCl.

The data cited provide a basis for presuming that shot blast hardening will also increase corrosion-fatigue resistance under atmospheric corrosion conditions.

In the corrosion-fatigue testing of shot blasted specimens, it was shown that humid air, in the presence of sulfur dioxide, decreases the resistance from 35 to 31 kg/sq mm, i.e., by 11.5%. However, in comparing the corrosion-fatigue curves [given in article; not reproduced in this report] plotted for specimens in an atmosphere of humid air with a 0.27% SO_2 content which were not cold hardened by shot blasting with those which were so cold hardened, it is clearly seen that shot blasting increases corrosion resistance in this medium from 24 to 31 kg/sq mm, i.e., by 29%.

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Therefore, shot blasting may be regarded as a suitable means of increasing the fatigue strength of structural steel subject to atmospheric corrosion (humid air containing SO_2).

The metallographic analysis of shot blasted specimens subjected to corrosion-fatigue tests under atmospheric corrosion conditions indicated corrosion-fatigue fractures.

Test Results of Surface Hardened Specimens

Induction hardening is used primarily as a means of increasing wear resistance as well as increasing fatigue strength. The effectiveness of induction hardening parts subject to fatigue cannot be doubted. In many cases, service life of vital parts was lengthened as a result of induction hardening.

Experiments conducted in the Central Scientific Research Institute of Heavy Machine Building, however, uncovered a new and very valuable property of induction hardened steel -- its high corrosion-fatigue strength in many liquid, corrosive media.

This characteristic of steel, as well as its high fatigue strength, results primarily from the considerable residual stresses in the hardened surface.

The cause of these residual stresses is, in this case, the structural transformations occurring in the metal during heat-treatment. Consequently, it was of great practical interest to test induction hardening as a means of increasing corrosion-fatigue strength under atmospheric corrosion conditions.

Induction hardened grade 45 steel specimens were tested in two media: in air and in an atmosphere of moist air containing 0.27% SO_2.

From the curves [given in article; not reproduced in this report] plotted on the basis of the tests, it can be seen that a corrosive atmosphere of humid air containing sulfur dioxide decreases the strength of surface hardened steel by 16%. In this medium, however, surface hardened steel has a considerably greater corrosion-fatigue resistance than nonhardened steel. In point of fact, nonhardened steel specimens have a resistance of 24 kg/sq mm, while induction hardened specimens have a resistance of 52 kg/sq mm.

On the basis of these tests, induction hardening can be considered an altogether suitable means of increasing the corrosion-fatigue strength of parts subject to atmospheric corrosion.

Test Results of Nitrided Specimens

Nitriding is now widely used as a means of increasing the service life of many vital parts.

There are two types of nitriding: hardening and anticorrosion. Anticorrosion nitriding is an effective method of increasing the corrosion-fatigue strength of structural steel.

Experiments conducted at the Central Scientific Research Institute of Technology and Machine Building indicate that the fatigue resistance of grade 35 steel, as a result of a short-term nitriding is increased 40% when tested in air, and 116% when tested in water.

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The high corrosion-fatigue resistance of nitrided steel results from the following circumstances: in the nitriding process, as in other types of surface hardening, desirable residual stresses of compression occur in the peripheral layer of the metal which considerably diminish the sensitivity of the metal to stress concentrations. Moreover, nitriding causes steel to acquire good protective properties in such media as water and industrial atmospheres.

Tests were conducted on nitrided specimens of grade 45 steel to check the effectiveness of anticorrosion nitriding as a means of increasing the fatigue resistance of structural steel when subjected to atmospheric corrosion.

The specimens were nitrided at a temperature of $600^{\circ}C$ for 1.5 hours with a 45% ammonia breakdown in electric furnaces.

As a result of nitriding, the corrosion-fatigue resistance of grade 45 steel, in an atmosphere of humid air containing sulfur dioxide, increased from 24 to 34.8 kg/sq mm, i.e., by 45%.

On the basis of these data, short-period nitriding can be regarded as one possible means of increasing the fatigue strength of parts subject to atmospheric corrosion.

Conclusions

All the investigated types of surface hardening, i.e., shot blasting, induction hardening, and nitriding, considerably increase the alternating-stress strength of grade 45 structural steel in an atmosphere of humid air containing 0.27% SO_2. The most effective method of increasing corrosion-fatigue resistance under atmospheric corrosion is through high-frequency induction hardening.

The corrosion resistance of grade 45 steel, in a medium of humid air containing sulfur dioxide was found to have been increased 29% when cold hardened by shot blasting, 117% when induction hardened, and 45% when anti-corrosion nitrided.

Literature

[Comment: Article lists 11 references under this heading; all are Soviet and ten show a publication date of 1948 or later.]

CAUSES OF BOILER DAMAGE

V. M. Nikiforova, Candidate of Technical Sciences
S. G. Vedenkin, Professor

Scope

This article studies the typical damages occurring in the steam boilers of river ships.

Previous studies have contributed considerably to understanding the reasons for the damages prevalent in river-craft boilers. However, these studies have not sufficiently examined questions pertaining to the physicochemical processes involved in the destruction of boilers.

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To conduct the tests described in this article, some metal specimens cut from damaged portions of ship steam boilers manufactured in various years (1903-1935) were sent to the corrosion department of the Central Scientific-Research Institute of Technology and Machine Building. [Comment: Article gives data on the damaged boilers and photographs of the specimens therefrom.]

The most characteristic defects in the metal consisted of fractures and corrosion. The determination of the character and the causes of these defects was broken down as follows: chemical and metallographic analyses of the specimens, determination of the physical properties of the metal (strength, yield point, proportional limit, coefficient of compression, etc.), determination of the quality of the water used, and establishment of special tests for studying the effect of structural changes in 3K boiler steel on resiliency (at various temperatures) and the tendency toward fracture while subjected to stress and aggressive liquid media.

Chemical Composition

In its chemical analysis, the metal of most of the damaged boiler parts was satisfactory. [Comment: Article gives results of the chemical analyses for the various boilers.] Except for one boiler, it is believed that the composition of the metal had no noticeable effect on boiler damage. In all cases except two the steel was rimmed.

The authors believe that river-ship boilers should be made of the 15K and 20K steel which is currently being used for stationary boilers.

Physical Properties and Steel Structure

The results given in article of the physical tests run on specimens taken from damaged boilers indicate that the metal itself is not defective. The tensile strength and plasticity of the metal are normal for boiler steel. Therefore, the resultant damages in the boilers cannot be ascribed to unsatisfactory physical properties.

The results [given in article] of the metallographic analyses indicate that in some of the boilers there occurred the complete or nearly complete dissociation of pearlite with the formation of structurally free cementite. This indicates that the damaged parts of these boilers were operated at very high temperatures.

Characteristics of Boiler Damage

Intercrystalline fracture occurred in two of the ship boilers.

Thermophysical fractures, with fracture in the firebox (intracrystalline) occurred in one of the boilers, while fracture in the steam chamber (under a thick layer of scale) occurred in two of the boilers. Fractures resulting from unsatisfactory physical properties in the metal (low resiliency at 0°C) with a simultaneous violation of maintenance repair were found in one boiler. Another boiler had fractures which could be ascribed to an unsatisfactory chemical composition (high phospherus and sulfur content).

Corrosion damage to boiler parts subject to alternating stress and aggressive media (stress corrosion) occurred in two cases.

The following factors were found to be responsible for the intercrystalline corrosion of boiler parts: high alkalinity of boiler water with low content of soluble salts, the presence of high stresses in portions of the boiler causing admixtures to become separated from the boiler water (admixtures

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which are active in relation to the stressed metal), and the presence of gaps and small cracks in the boiler into which the water can seep and in which the admixtures are deposited once the water evaporates.

There is still no uniformity or clarity of thought on the mechanics of the action of alkali on stressed metal.

Investigations make it possible to establish a relationship between the stability of boiler steel subject to tensile stress and the concentration of the alkaline solution. The higher the concentration, the less the resistance of the metal when under uniform stress.

Individual boiler parts may be operated under alternating stress. Among such parts are the firebox walls. When the firebox is heated, the metal on the fire side expands to a greater degree than the metal on the water side. If this cycle is repeated several times, corrosion-fatigue fractures may appear. High temperatures and aggressive gases may serve to decrease the fatigue limit of steel under such circumstances.

The principal types of corrosion damage in steam boilers are damage in the water chamber of the boiler caused by electrochemical corrosion, and damage in the firebox caused by gas (chemical) corrosion.

Since carbon steel is resistant to gas corrosion in the 400-450°C temperature range, such corrosion may occur only as a result of abnormal operating conditions and considerable scale deposits. In such cases, the firebox wall temperatures may rise to 500°C and more.

Methods of Preventing Fracture and Corrosion in Steam Boilers

Fractures and corrosion are the result of the simultaneous action of many factors. Their prevention, therefore, should also proceed along several lines. The following measures can be recommended: the use of stronger and more corrosion-resistant metal in boilers and fireboxes, improvements in boiler design to decrease stress concentrations, heating and degasification of water before its introduction into the boiler, and improving the water processing and eliminating the possibility of thick scale formations.

Our research on the corrosion resistance of steels indicated the advisability of using the low-alloy, chromium-nickel-copper NL-2 steel with a somewhat decreased carbon and copper content. This steel was found to be superior to carbon steel in its corrosion-resistant properties.

Conclusions

The thorough study of metal specimens taken from ten damaged river-ship boilers indicated that the damage resulted from both fractures and corrosion.

This article provides a detailed analysis of the possible causes of fracture and corrosion in relation to metal quality, boiler design, and operating conditions (water quality).

The initial quality of the metal, studied in relation to chemical composition and physical properties, in all cases but one (which had a very high sulfur content) corresponded to normal boiler steel and therefore may not have been the cause of the damages.

Metallographic examinations indicated that metal from some of the boilers had an abnormal structure.

The appearance and growth of fractures in most of the boilers was the result of high thermophysical stresses caused by high temperature drops in some parts of the boilers.

Some fractures can be ascribed to the boiler water, to cold repair, and to poor welding.

Corrosion in some boilers was the result of the simultaneous action of aggressive admixtures in the water (oxygen, carbon dioxide, and soluble salts) and great stresses which destroyed the protective oxide coating.

Suggestions have been made as to how boilers can be improved and protected from fractures and corrosion.

Literature

[Comment: Article cites eight Soviet references, four of which show publication dates of 1950 or later.]

EFFECT OF TECHNOLOGICAL FACTORS ON INTERNAL STRESS IN THE ELECTROLYTIC DEPOSITION OF CHROMIUM

A. V. Rykova, Candidate of
Technical Sciences

Introduction

Chromium plating is used to provide resistance to corrosion and wear.

Porous chromium plating, primarily to increase the wearability of piston rings and cylinders in internal-combustion engines, has lately come into wide use. The presence of pores in the chromium-plated surface also serves to facilitate lubrication.

A major disadvantage of chromium plating is internal stress. Considerable tensile stresses emerge in chromium electroplating because of the strong bond between the chromium and the base metal and, if the tensile stress of the plate exceeds the base metal tensile strength, fracture results.

Although internal stresses in galvanic plating are of great practical and scientific interest, the matter has been insufficiently studied, especially as it pertains to chromium.

This article is concerned with the study of the relationship between the degree of internal stress in electroplated chromium and the following factors: current density, temperature and concentration of the electrolyte, plate thickness, cathode material and the preparation of its surface before plating, and the quantity of atomic hydrogen absorption during the electrolytic process.

Review of the Literature

[Comment: Article contains an extensive discussion of previous research on this topic.]

Method

Of the two existing methods of studying internal stress in galvanic plates, the flexible-cathode and the X-ray method, the first was selected.

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The advantage of this method is that in X-ray analysis it is possible to measure stress only after the termination of electrolysis, and then only in a thin surface layer, whereas with the flexible-cathode method it is possible to study stress during the electrolysis process itself.

The flexible-cathode method consists of placing a galvanic coating on one side of a steel plate and lacquering the other. During the electrolysis process, the plate flexes toward the galvanic coating. These flexures indicate tensile stresses.

[Comment: Article describes specimen selection and preparation, testing equipment, and test processes.]

The relationship of internal stress in electroplated chromium to current density and temperature was studied at 50, 55, and 60° temperatures and at current densities of 10, 15, 25, 30, 35, 50, 80, 90, 100, and 120, amp/sq dm. The test results indicated that at a temperature of 65°C and a current density of 15 amp/sq dm the stress is greater than at current densities of 25-35 amp/sq dm; in increasing current density to 80 amp/sq dm, stress rises to 37 kg/sq mm. If density is then increased to 120 amp/sq dm, the stresses in the chromium plate do not rise but even fall a little.

At temperatures of 50 and 55°C, the reverse is true: as current density is increased to 35 amp/sq dm, internal stress increases but then slowly decreases.

Tests indicate that the hardness of the electroplated chromium increases as the current density is increased to 80 amp/sq dm but then begins to drop. The degree of internal stress, therefore, is dependent primarily on current density and temperature. [Article gives relationship curves.]

[Comment: The article also discusses the effect of chromic acid concentration on internal stress, the effect of plate thickness on internal stress, the effect of cathode material and cathode surface preparation on internal stress, and the development of chromium and nickel plating methods to decrease internal stress. The results of these tests are given. They are summarized by the author in her conclusions.]

Conclusions

This investigation warrants the following conclusions:

1. It has been established that there are residual tensile stresses in electroplated chromium, whatever the factors involved.

The stresses in electroplated chromium are as high as 37 kg/sq mm at a plate thickness of 30 microns. Current density and electrolytic temperature have a very great effect on degree of stress.

2. A relationship has been established between residual tensile stress and plate structure and hardness.

3. It has been established that the microgeometry of the surface of the base metal has a substantial effect on the degree of internal stress in chromium plate.

4. It has been found that there is no direct relationship between the hydrogen content in the chromium plate and the internal stress.

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5. The previously suggested hypothesis that a decrease in fatigue strength as a result of chromium plating is caused by the high residual tensile stresses which occur in the chromium plate during the electrolytic process has been experimentally confirmed.

6. The heat-treatment of chromium-plated parts (200-250°C) decreases the strength by 30%. Experimental investigations have shown that annealing chromium-plated specimens at 450-550°C significantly decreases internal stresses almost to the vanishing point and effects a corresponding increase in the strength of the steel.

On the bases of the investigations conducted, the following means of eliminating internal stresses in chromium and nickel platings may be recommended:

1. The surface should be carefully polished before plating.

2. In parts subject to alternating stresses, low current densities should be used, 25-35 amp/sq dm, at 65°C, and 80-100 amp/sq dm at 50-55°C.

3. Chromium-plated parts should be annealed at temperatures higher than those currently used, namely at 400-450°C. There was no decrease in chromium plate hardness observed in this temperature range. If the operating conditions do not require great hardness, it is more expedient to anneal at 650°C.

Literature

[Comment: Article cites 32 references including 23 Soviet. Two of the Soviet sources bear publication dates of 1950 or later.]

EFFECT OF TECHNOLOGICAL FACTORS ON INTERNAL STRESSES IN NICKEL PLATINGS

A. V. Rykova, Candidate of Technical Sciences

Relationship of Internal Stress to Current Density, Temperature, and Electrolytic Composition

Some data have been published on the relationship of internal stress in nickel platings to temperature, composition of electrolyte, and current density. In most cases however, the research was conducted under dissimilar conditions, not permitting a comparison of the results.

My investigation of internal stress was by the flexible-cathode method. Steel plates made of grade 10 steel were used as the cathodes.

The effect of internal stress on the strength of nickel plated specimens was studied on specimens made of grade 45 structural carbon steel.

Before making the specimens, the blanks were normalized at 840-860°C.

The tests indicated that stress increases as current density is increased; stress is greatest (28 kg/sq mm) at 5 amp/sq dm.

Tests also indicated that an increase in electrolytic temperature decreases stresses in the plating.

It was found that an acidity of the electrolyte solution of pH 4.5, 5.0, 5.5, and 5.7 does not affect internal stress.

Investigations showed that the internal stresses in nickel plate at a current density of one amp/sq dm and an electrolyte temperature of 20°, has no relation to the cathode material, but depends rather on the condition of the cathode surface.

Effect of Electrolyte Composition on Internal Stresses of Electroplated Nickel

As previously stated, nickel plate has considerable residual tensile stress (up to 28 kg/sq mm) when deposited from an electrolyte with a nickel sulfate concentration of 250 g/l. Nickel deposited from an electrolyte with a 350 g/l concentration of nickel sulfate, however, has internal stresses of only 6-9 kg/sq mm.

It was shown that nickel deposited from ordinary electrolyte causes a sharp drop in the strength of steel (by 62%). However, nickel deposited on steel by electroplating from electrolytes with a high nickel content decreased the fatigue strength of steel by only 8%.

Conclusions

Internal stresses in nickel plate increase as the current density increases and decrease as the temperature increases.

Changing the acidity of nickel electrolyte within the range pH 4.5-5.7 has no effect on degree of stress in nickel deposits.

Stirring the electrolyte decreases the stress in nickel deposits.

Nickel deposited from an electrolyte with 350 g/l of nickel sulfate (at pH 1.2) has an internal stress of 7.5 kg/sq mm, whereas nickel deposited from ordinary electrolyte has stress of up to 28 kg/sq mm.

Through the judicious selection of electrolyte and the electroplating process, it is possible to deposit nickel with altogether insignificant internal stress.

Literature

[Comment: Article cites four Soviet references, all published since 1945.]

COMPARISON OF INTENSITY OF CORROSION IN CAST IRONS AND STEELS IN VARIOUS MEDIA

M. G. Timerbulatov, Candidate of Technical Sciences

Introduction

One of the important technical achievements of contemporary foundry work is the development of the production of spheroidal graphite cast iron, first called superstrong cast iron. This new structural material, because of its good properties, is used in place of ordinary gray iron, nodular iron, malleable iron, and carbon steel.

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This article lists the results of corrosion tests run on spheroidal graphite cast iron in an industrial atmosphere, in an acid medium (where the separation of hydrogen accompanies the corrosion process), and in fresh water and sea water. Two grades of spheroidal graphite cast iron were tested. As a comparison, specimens of common gray iron and grade 30L carbon steel were also tested. [Comment: Article shows the microstructure and chemical compositions of all specimens.]

Tests in a 3% Solution of Sulfuric Acid

Tests were conducted at a temperature of 25°C. After 6 hours, the SPCh-P-45 iron with a pearlitic and pearlitic-ferritic structure, had the greatest corrosive resistance. The SPCh-F-10 iron with a ferritic structure and gray iron SCh 21-40 had the least; midway was the 30L steel. [Comment: Article gives specific figures on the corrosion of these specimens as well as an extended explanation of why one spheroidal graphite cast iron corroded more than the other.]

The results of these tests have shown that in a 3% solution of sulfuric acid the rate of corrosion of ferrous metals is dependent largely on their structure, internal stress, and admixtures. The rate of corrosion of spheroidal graphite cast irons with a pearlitic and pearlitic-ferritic structure is eight times greater during the first 6 hours than the corrosion of cast iron with a ferritic structure, SPCh-F-10.

Spheroidal graphite cast irons, just like grade 30L steel and gray iron, are not stable materials in acid solutions where hydrogen separation occurs.

Tests in a Humid Chamber

The principal factors determining the rate of atmospheric corrosion in an industrial region are humidity and aggressive gases.

To evaluate the corrosive properties of the materials under study, laboratory tests were conducted in a humid air chamber with an addition of sulfur dioxide.

The rate of corrosion of the SPCh-F-10 cast iron is somewhat greater than that of the other materials during the first few days.

All in all, however, there is little distinction between the corrosion resistance of cast irons. The 30L steel is somewhat less susceptible to corrosion in a medium of humid air and aggressive gases than are the cast irons.

Atmospheric Corrosion Tests

Atmospheric corrosion tests were conducted on the roof of the Central Scientific Research Institute of Technology and Machine Building, where the atmosphere is highly polluted with industrial gases and is sufficiently aggressive. The SPCh-F-10 cast iron had a higher degree of corrosion, as it did in the laboratory tests. This is probably because the products of corrosion do not adhere well, fall off, and thus do not serve to protect the base metal. However, the SPCh-P-45 cast iron is not far removed from the SPCh-F-10 iron. The 30L steel curve is somewhat below that of the irons. After about 90 days of exposure, however, the curves flattened out, probably because the products of corrosion were sufficiently thick to protect the specimens.

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These tests allow the following conclusions:

Spheroidal graphite cast irons with a pearlitic and pearlitic-ferritic structure are affected by atmospheric corrosion just as much as is gray iron. The SPCh-F-10 cast iron undergoes more intensive corrosion; after a 4-month test in an industrial atmosphere, the SPCh-F-10 iron underwent a 30% greater corrosion than did gray iron.

The 30L steel is somewhat less subject to industrial atmospheric corrosion (in 120 days, 18% less than gray iron, and 8-50% less than spheroidal graphite cast irons).

Cast-iron corrosion in an industrial atmosphere is considerably decreased if the specimens have a casting skin.

Tests in a 3% Solution of Sodium Chloride

Tests were run in a 3% solution of sodium chloride to evaluate the behavior of the materials in sea water.

All the cast irons and the 30L steel were subject to about the same degree of corrosion.

Tests in a Spindle Apparatus

When metal is agitated in water and the water flow is increased, corrosion is generally intensified because of the increase in the quantity of oxygen in contact with the surface of the metal. Tests were conducted in a spindle apparatus to study this phenomenon.

It was seen that spheroidal graphite cast-iron corrosion is decreased as the ferrite in the structure is increased. After a 90-day test, the corrosion of SPCh-F-10 cast iron with a ferritic structure was 23 and 28% less, respectively, than the corrosion of SPCh-P-45 cast iron with a pearlitic-ferritic and a pearlitic structure.

The corrosion resistance of the SPCh-P-45 cast iron with pearlitic-ferritic structure was the same as the corrosion resistance of gray iron, while the corrosion resistance of SPCh-P-45 cast iron with a pearlitic structure was only 6% less.

The 30L steel had a 17% greater corrosion resistance than gray iron.

Thus, the SPCh-F-10 cast iron with a ferritic structure is more corrosion resistant than other cast irons and 30L steel.

[Comment: Article includes a table listing the unit rates of corrosion of cast irons and steels in various media.]

Conclusions

1. The rate of corrosion of ferrous metals in a 3% solution of sulfuric acid depends primarily on their structure, internal stresses, and admixtures. The corrosion intensity of spheroidal graphite cast irons with pearlitic and pearlitic-ferritic structures during the first 6 hours of exposure was about eight times greater than that of the SPCh-F-10 cast iron with a ferritic structure. Neither spheroidal graphite cast irons, 30L steel, nor gray iron can be regarded as corrosion resistant materials in acid solutions.

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2. Spheroidal graphite cast irons with pearlitic and pearlitic-ferritic structures undergo about the same corrosion in an industrial atmosphere as do the gray irons. The SPCh-F-10 cast iron undergoes a somewhat more intensive corrosion.

3. A casting skin on the surface of cast irons greatly decreases their corrosion in an industrial atmosphere.

4. All the cast irons studied as well as the 30L steel undergo equal corrosion in a 3% sodium chloride solution. It can be assumed that, in at least the initial period, these materials have the same corrosion resistance to sea water.

5. The SPCh-F-10 cast iron is more resistant to corrosion than other cast irons (up to 38%) in flowing water.

Literature

[Comment: Article cites six Soviet references, four of which bear publication dates of 1950 or later.]

INVESTIGATION OF CORROSION RESISTANCE OF EI496 STEEL IN REFINING OF SULFUROUS PETROLEUM

Ye. D. Surovtseva, Engineer
Ye. M. Lapitskaya, Engineer
N. V. Sukhobokova, Engineer

Introduction

The increase of operating temperatures and pressures in the refining of sulfurous petroleum has increased the acuteness of the need of combating corrosion.

In recent years, the low-carbon, high-chromium EI496 steel has been widely used in the manufacture of corrosion-resistant oil equipment. This steel is used primarily to clad other metals. The EI496 steel, as distinguished from carbon steels, has a high degree of corrosion resistance against the action of sulfur compounds at high temperatures (hydrogen sulfide, etc.). Nonetheless, in some media (containing hydrogen chloride and water or sulfur compounds and hydrochloric acid), this steel is not corrosion resistant. However, there are no published data on the corrosion resistance of EI496 steels used in refining sulfurous petroleum or on the corrosion resistance of welded joints in high-chromium steel.

This article examines the corrosion resistance of EI496 steel, welded joints of this steel, and St 3 steel as used in oil-refining equipment.

Conclusions

1. The EI496 steel underwent practically no corrosive destruction (weight loss during 12 months was 0.026 g/sq m hour). There was practically no change in thickness.

2. The St 3 steel underwent considerable corrosive destruction (weight loss during 12 months was 1.86 g/sq m hour, thickness decrease of 5.98 mm/year).

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3. Welded joints in EI496 steel, with nonstabilized type 25-20 electrodes, had a tendency toward intercrystalline corrosion.

4. Welded joints in EI496 steel, with stabilized type 18-8 electrodes with niobium, had no tendency toward intercrystalline corrosion.

METHOD OF TESTING STEEL FOR GAS CORROSION AT HIGH TEMPERATURES

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The investigation of gas corrosion in metals at high temperatures is one of the most difficult, lengthy, and least-developed corrosion study.

There are many methods for studying gas corrosion; nearly every researcher develops his own individual method.

It is thus difficult to obtain any comprehensive picture of high-temperature gas corrosion or even to compare the results of tests run on the same materials.

This situation indicates the great need of establishing a uniform procedure for testing the high-temperature corrosion resistance of metals and alloys.

[Comment: Article describes in some detail the method developed at the Central Scientific Research Institute of Technology and Machine Building for testing the gas corrosion resistance of metals at temperatures of 300-1,100° C.]

Conclusions

The method for the high temperature testing of steels described herein served as the basis for the creation of a GOST (state all-union standard) for the testing of steel for gas corrosion at high temperatures.

Literature

[Comment: Article cites five sources, three of which are Soviet, none later than 1947.]

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